1.3 The Web of Life

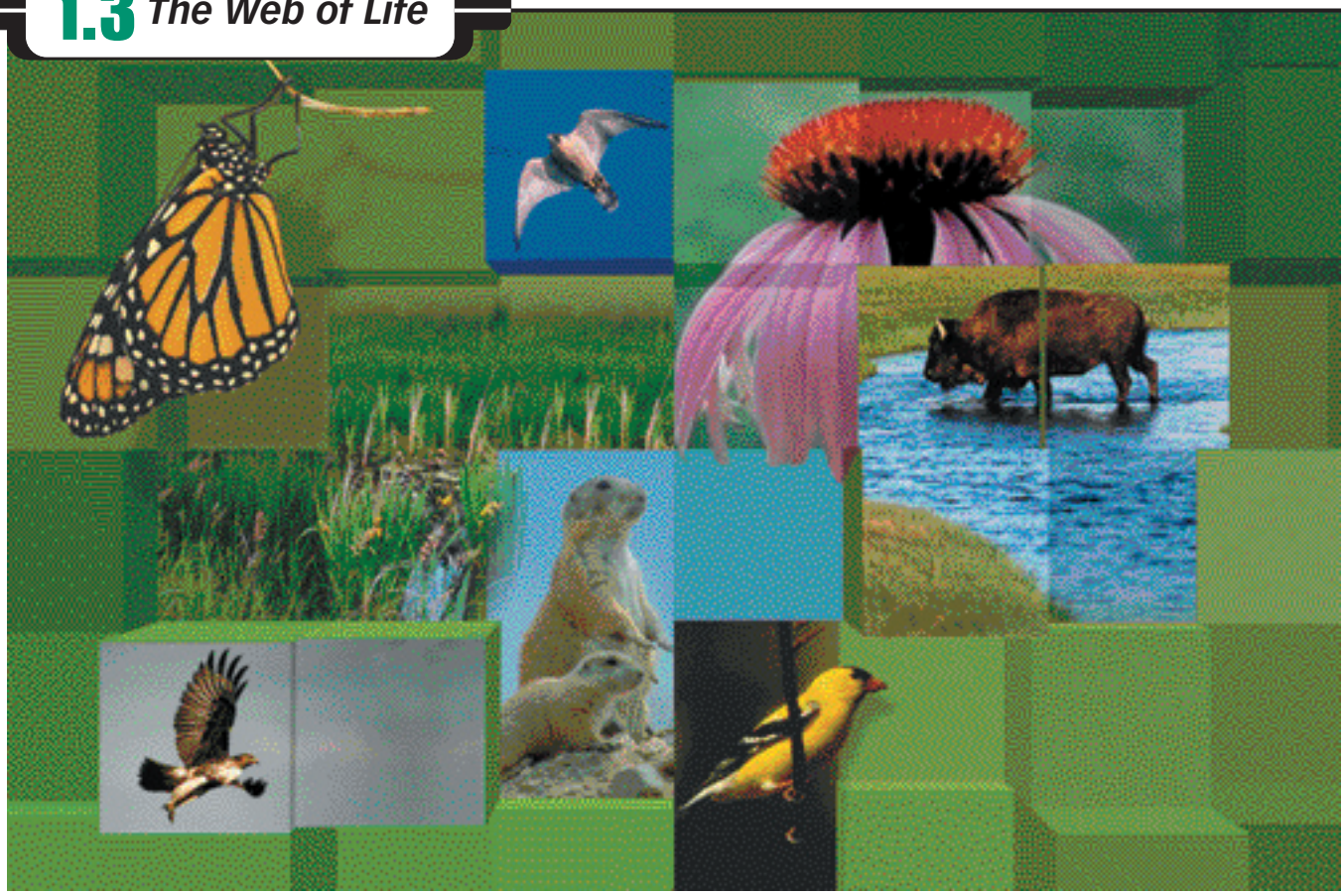


Figure D1.27: An ecosystem is an ecological system.

Earlier in Chapter 1 you were introduced to some organisms found in the prairie grassland environment, to the interactions between them, and to their connections to the physical environment. This is called an ecosystem because it is an ecological system: key parts are organized in specific ways so the whole system can function in a sustaining way. In Lesson 1.3 you will have opportunities to discover how the organization of this system transfers energy to each individual organism.

Roles of Organisms

What is the initial source of energy for organisms in the prairie grassland ecosystem? It all starts with energy from the Sun being captured by grasses and wildflowers through the process of photosynthesis. The green plants, algae, and tiny aquatic organisms, called phytoplankton, that convert light energy and store it in the chemical bonds of organic molecules are called **producers**. These photosynthetic organisms produce the organic compounds of food from inorganic nutrients found in soil, air, and water.

The other organisms that rely either directly or indirectly upon producers as a source of food are called **consumers**. Consumers that eat plants or algae are called **primary consumers** or **herbivores**.

Figure D1.28: A grasshopper is a herbivore.

- producer: an organism that uses light energy to synthesize sugars and other organic compounds through the process of photosynthesis
- consumer: an organism that uses other organisms as a source of energy
- primary consumer or herbivore: an organism that eats green plants, algae, or phytoplanktons

In the prairie grassland ecosystem, grasshoppers would be herbivores because they eat the leaves of grasses and other plants. Since grasshoppers are sometimes eaten by yellow warblers and other birds, the yellow warblers are called **secondary consumers**. The process doesn't stop with the yellow warblers, because they could be eaten by peregrine falcons, which are called **tertiary consumers**. Since both the yellow warblers and peregrine falcons are killing and eating other animals, they can also be called **carnivores**.

Of course, not all animals fit nicely into these categories because some animals are opportunists and seem to eat a wide variety of foods. Sparrows will eat both seeds and insects. Skunks prefer to eat insects, but they will also eat bird eggs, berries, and mice. Since they are not strictly herbivores or carnivores, they are called **omnivores**. Skunks have also been known to eat the meat of animals that have died from accidents, illnesses, or predation by some other animals. In these cases, the skunk is acting as a **scavenger**.

Notice that the word *scavenger* is usually reserved for larger organisms that feed on meat. **Decomposers** are the smaller organisms that complete the decay process by returning all organic material to inorganic material. Decomposers play a critical role in the ecosystem because they act on all dead plant and animal matter to provide the essential inorganic compounds required by the producers that support the entire system.

- secondary consumer: an organism that eats herbivores
- tertiary consumer: an organism that eats secondary consumers
- carnivore: an organism that kills and eats other animals
- omnivore: an organism that eats both plants and animals
- scavenger: a bird or animal that feeds on dead and decaying animals that it did not kill itself
- decomposer: an organism that breaks down complex, organic molecules into simpler molecules

Figure D1.29: Skunks are omnivores that often act as scavengers.

Practice

21. This table summarizes roles of organisms within the prairie grassland ecosystem. Complete the table by adding missing information. You may copy the table into your notebook or set one up with computer software.

ROLES OF ORGANISMS WITHIN THE PRAIRIE GRASSLAND ECOSYSTEM

Category			Description of Role	Examples
producer			• uses photosynthesis to convert light energy into chemical energy	
consumer	herbivore	primary consumer		
	carnivore			• cowbird • swift fox
			• obtains energy from other carnivores	
		primary, secondary, and tertiary consumer	• obtains energy from both plants and animals	
	scavenger			
decomposer				

DID YOU KNOW?

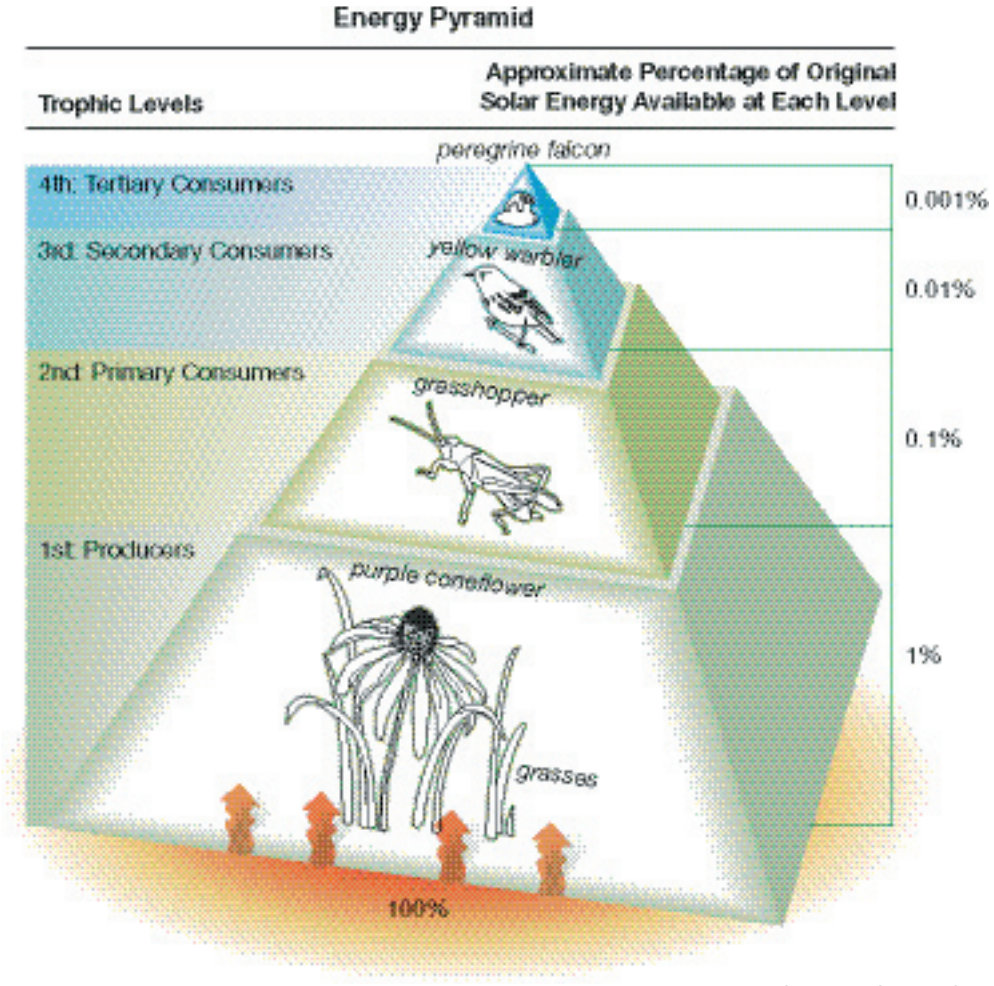
Two of Alberta's endangered species are the burrowing owl and the swift fox. The burrowing owl nests in the abandoned burrows of other animals, especially prairie dogs. Burrowing owls prey mostly on insects, but they will also eat small birds and rodents. The swift fox is the smallest North American wild dog—about the size of a cat. The swift fox depends on the prairie dog as its main food source. Its preferred habitat is the abandoned dens of prairie dogs located near hilltops.

Energy Flow in an Ecosystem

The primary source of energy for a prairie grassland ecosystem is light energy from the Sun. This is the case for almost every ecosystem on Earth. This energy is stored in the chemical bonds of large organic molecules, such as sugars, starches, fats, and proteins. This energy becomes available to herbivores when they feed on the plants. Each step in the energy pathway through an ecosystem is called a **trophic level**. This is illustrated in "Energy Pyramid."

trophic level: the division of species within an ecosystem based upon its energy source

Trophic comes from the Greek word *Trophikos*, which means to nourish. Each trophic level describes the food sources for all the organisms on that feeding level. The third trophic level is comprised of carnivores that eat herbivores. The fourth trophic level is made up of carnivores that eat other carnivores. Note that omnivores and scavengers can be placed at the second, third, or fourth trophic levels depending upon what they happen to be eating at the time.



Energy Flow Through Trophic Levels

The pyramid shape is used in the "Energy Pyramid" diagram due to the energy available at each level. The producers are only able to store about 1% of the total energy available in sunlight. As you have learned from previous science courses, some of the solar energy is reflected back into space, whereas some evaporates water in the hydrological cycle. The plant itself must use some of the energy available for the producers' life processes. After all, if a green plant can be thought of as a photosynthesis machine or a sugar factory, it takes some energy to run the factory.

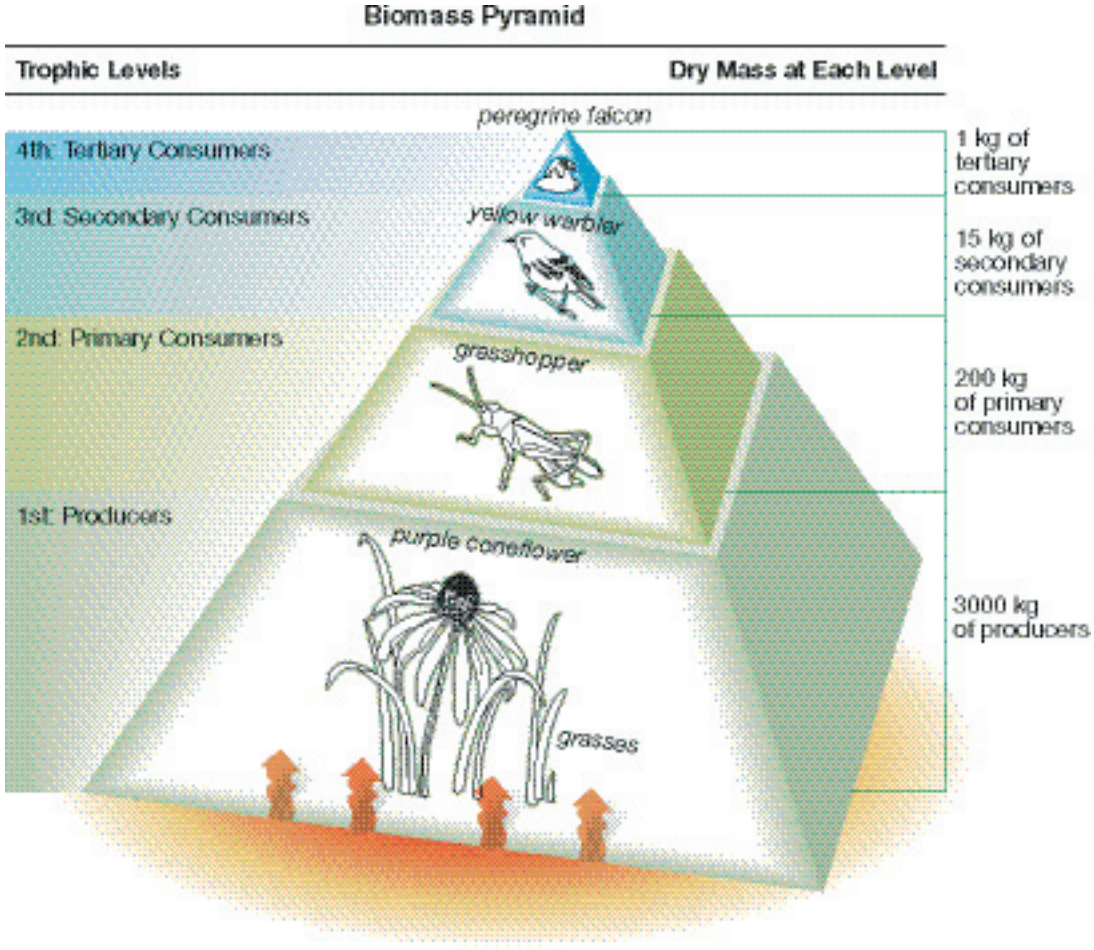
The same thinking applies to the grasshopper and other primary consumers. Of the 1% of sunlight energy made available to plants, herbivores can only store about one-tenth of that, or about 0.1% of the solar energy. This is because these organisms need to use energy to chew food, move around, reproduce, and complete other life functions. Energy used by the organism for life functions eventually leaves the ecosystem in the form of heat. This trend continues through each of the higher trophic levels, with only about 10% of the energy passed on to the next level. The important thing to remember is that energy is not recycled—it enters the ecosystem in solar-energy form and is ultimately passed from organisms back into the environment as heat.

Practice

22. The information shown in the "Energy Pyramid" highlighted only some of the organisms that you have been introduced to from the prairie grassland ecosystem. Other organisms would include additional forms of vegetation, black-tailed prairie dogs, bison, cowbirds, burrowing owls, swift foxes, sparrows, red-tailed hawks, skunks, and magpies. Determine the trophic level that best describes the nutrition source for each of these organisms. If some organisms are difficult to classify, concisely explain why.
23. Explain the following statement:

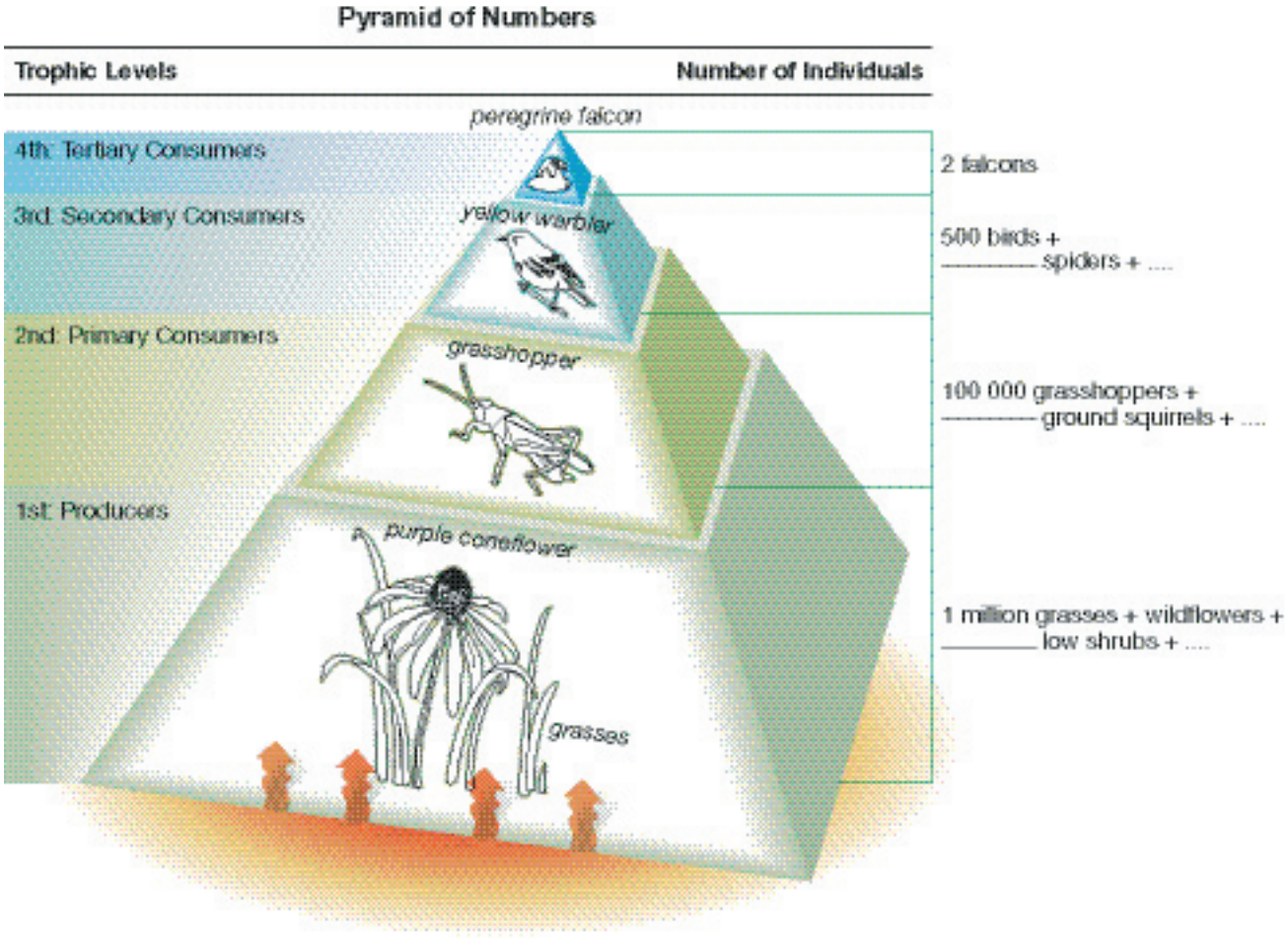
    Even organisms at the top of the energy pyramid will eventually have the energy that's stored in their bodies radiated into space as heat.

The Biomass Pyramid and the Pyramid of Numbers



Although the "Energy Pyramid" is a very useful model for understanding the flow of energy through an ecosystem, the total energy stored at each level is actually difficult to measure. As an alternative, biologists approximate the energy at each level by using a biomass pyramid. This means obtaining the dry mass of all organisms for each trophic level. It is important for the organisms to be dry because water contains no usable energy. In most ecosystems, the same pyramid shape is revealed, with only a fraction of the mass passed on to the next level.

An even simpler approach is to record the number of individual organisms at each trophic level. The result in this case is a graphic called the "Pyramid of Numbers."



The pyramid of numbers is another way to describe trophic levels. However, this approach has to be used cautiously because the size of individual organisms matters—one falcon has a dry mass of about 500 g, whereas a grasshopper has a dry mass of about 1.5 g. The ratio of 100 000 grasshoppers to 2 falcons has to be considered with this in mind. However, what is worth noting is that in this ecosystem, it takes more than a million producers to support the two top predators. From this point of view, you can see how fragile the situation is for the falcon—the number of these birds is very small, and these few birds must cover the large geographic area needed for the producers to support them as tertiary consumers at the top of the pyramid.

Practice

24. Explain why the trends shown on the "Pyramid of Numbers" can be misleading if they are interpreted without also considering mass.
25. Use the following information about DDT to answer questions a. to d.

Figure D1.30: DDT effectively kills mosquitoes.

One pesticide used extensively in the 1950s was DDT. This chemical was found to be very effective at killing mosquitoes that spread diseases like malaria. Once it was sprayed, DDT could remain active for a long time—it effectively killed the insects in an area. However, a significant disadvantage of using DDT was discovered.

DDT does not readily break down into less-harmful chemicals. Some organisms receive a quantity of DDT in their food that is too small to kill them. The chemistry of DDT means that organisms are unable to eliminate these chemicals from their bodies, so over time the DDT can accumulate. The DDT tends to concentrate in fatty tissues. The longer the organism eats food contaminated with DDT, the higher the concentration of DDT within the organism's fatty tissues.

Figure D1.31: DDT can affect a falcon's ability to reproduce.

a. Use the "Pyramid of Numbers" to explain why the concentration of pesticides like DDT in fat cells of birds that feed on insects can be hundreds of times greater than the concentration found in the actual insects.

b. A falcon may feed for years on insect-eating birds. This can result in a concentration of DDT that is hundreds of times greater in the fat cells of the falcon than it is in the birds it preys upon. Use the "Pyramid of Numbers" to explain this trend.

c. Given your answers to questions 25.a. and 25.b., explain why the concentration of DDT can become hundreds of thousands of times greater in the fat cells of falcons than it can in insects.

d. The accumulation of DDT in a falcon's body may not kill the bird but may affect the falcon's ability to reproduce. The eggs laid by falcons with concentrations of DDT in their bodies often have thin, easily-broken shells. Explain why it is important for modern pesticides to break down into harmless products a few hours or days after they are applied. Such pesticides are called non-persistent pesticides.

26. Infer reasons why predators at the top of the pyramid are so susceptible to extinction.

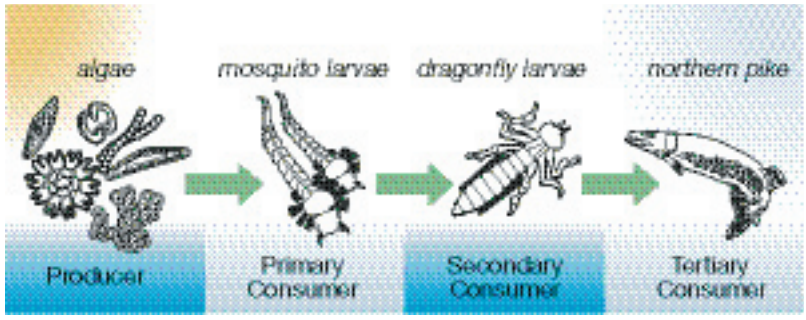
Food Chains and Food Webs

Ecological pyramids are useful organizers, but they do not provide detailed information about interactions between the populations of an ecological community. If you need this kind of information, a good place to start is a **food chain**. Food chains always begin with the producers and show how energy is passed along by one organism feeding on another. Food chains can be constructed for aquatic ecosystems as well. As was the case for the terrestrial food chain, this also starts with the producers.

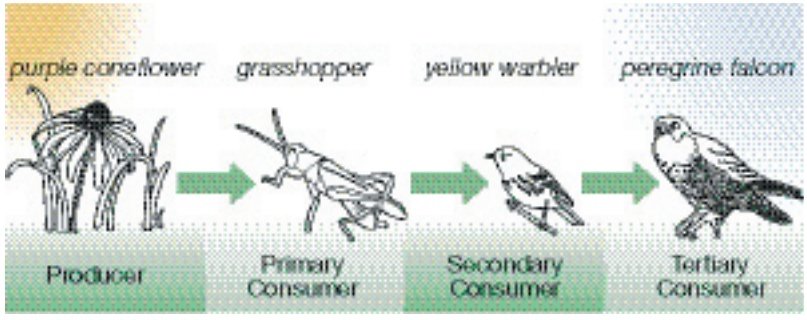
The strength of using a food chain to represent energy transfer is that it shows details of the feeding between trophic levels. This idea can be enhanced by showing the many food chains that comprise an entire ecosystem. Since the various food chains overlap and interconnect, this is called a **food web**.

- food chain: the pathway along which food is transferred from one trophic level to the next
- food web: the interconnecting feeding relationships within an ecosystem

Freshwater Food Chain

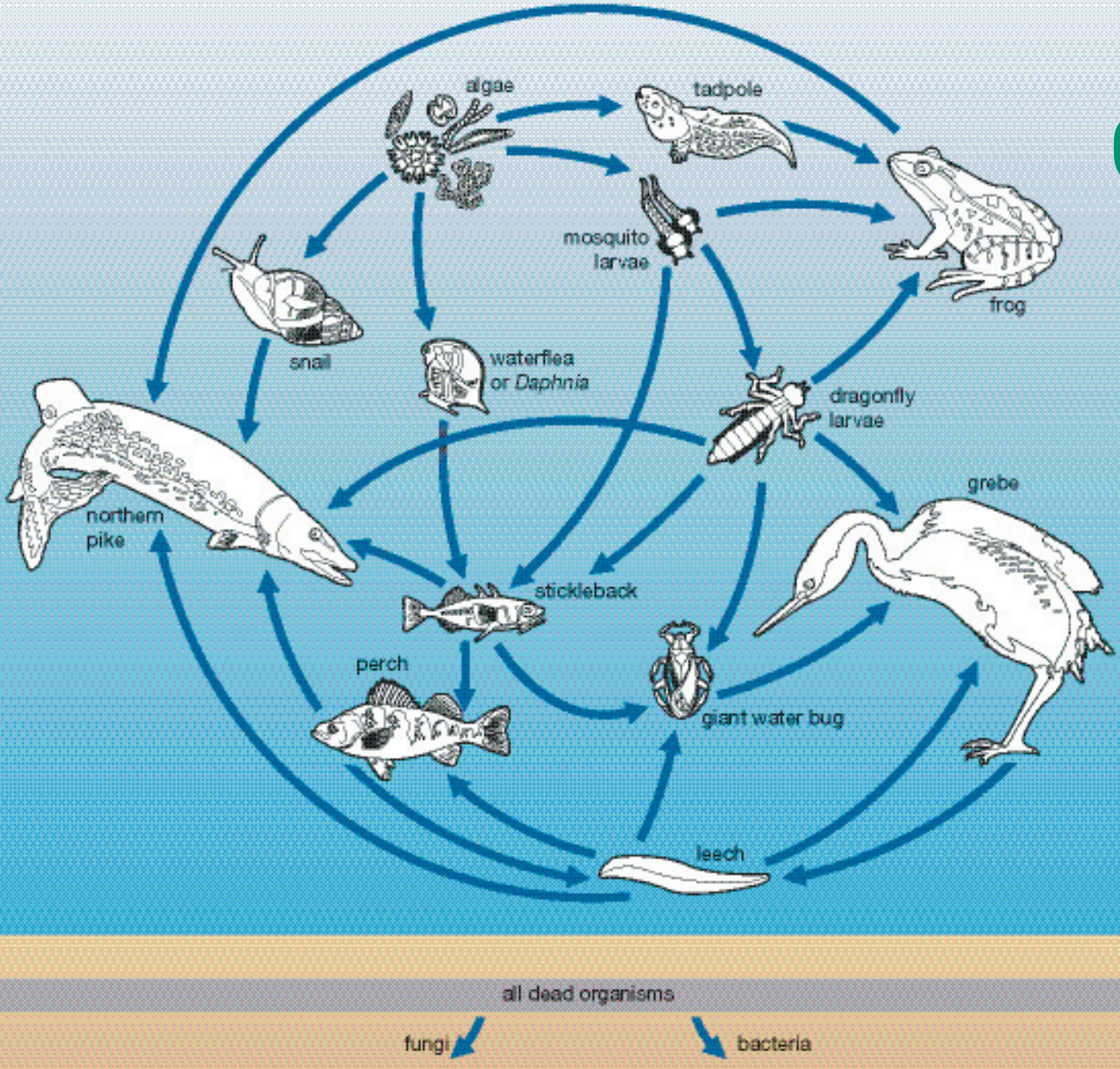


Prairie Grassland Food Chain

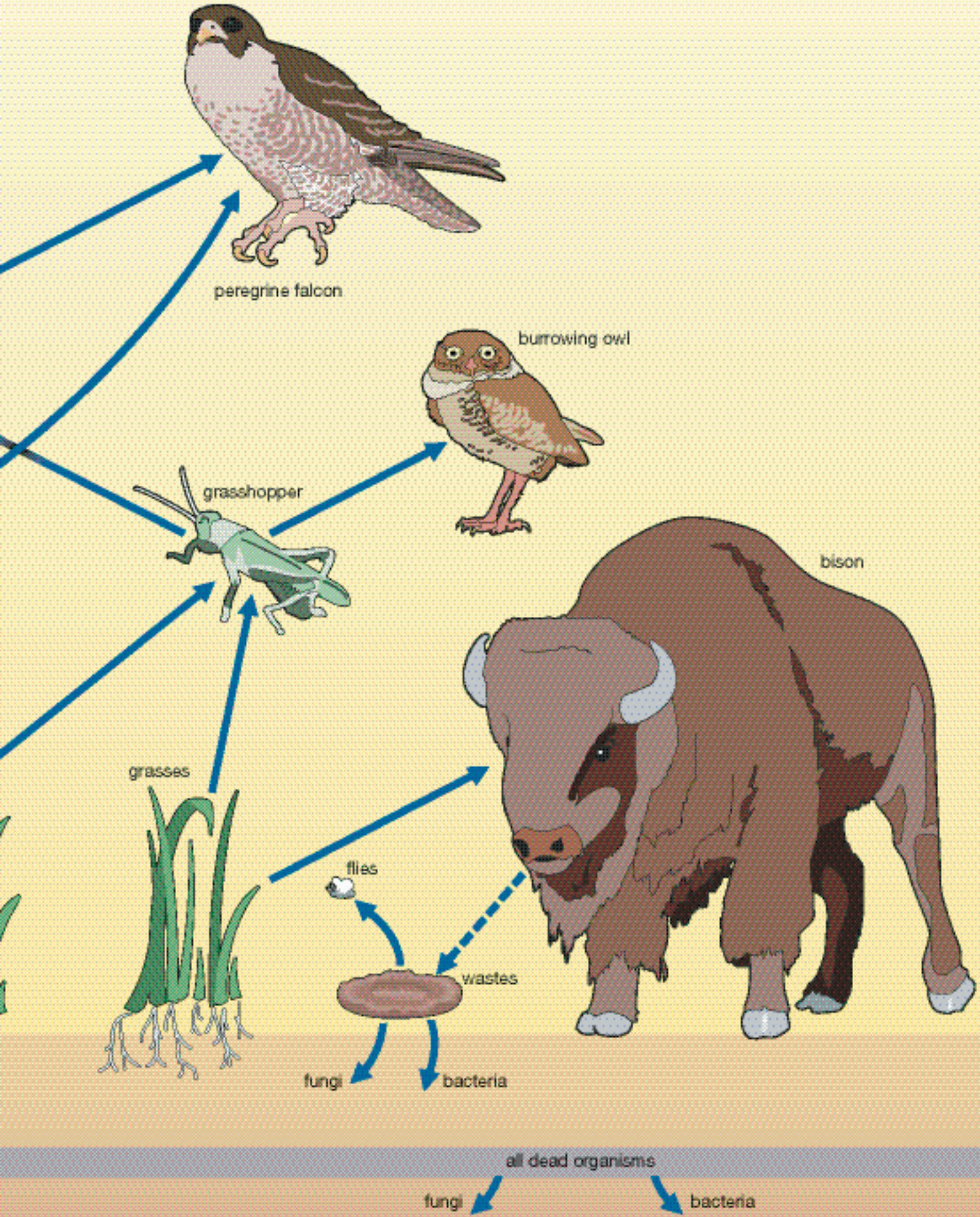


You can see that the two food web diagrams that follow not only contain everything from the previous food chains but also show the numerous interconnections.

Freshwater Food Web



Prairie Grassland Food Web
red-tailed hawk
yellow warbler
goldfinch
swift fox
black-tailed prairie dog
purple coneflower
grasses
bacteria living on roots
nematodes feeding on bacteria
all dead organisms
fungi
bacteria


peregrine falcon
burrowing owl
grasshopper
bison
grasses
flies
wastes
fungi
bacteria
all dead organisms
fungi
bacteria

Practice

27. Suggest an explanation for the term food web.
28. Examine the "Freshwater Food Web."
    a. Identify the producers in this food web.
    b. Identify the primary consumers or the herbivores.
    c. Identify the secondary consumers.
    d. Identify the tertiary consumers.
29. Examine the "Prairie Grassland Food Web."
    a. How does this food web communicate that producers occupy the first trophic level and generate the basic food that supports all other levels?
    b. How does this food web communicate that herbivores occupy the second trophic level?
    c. Relate which organisms have the greatest number of links between themselves and the producers.
30. Summarize your answer to question 28 by creating an energy pyramid for the freshwater ecosystem. Include a list of all the organisms that feed at each trophic level within your pyramid.

1.3 Summary

Producers, such as plants, make nutrients that can be used by other living organisms. Food chains are simple models that show how energy and matter move from producers to consumers and, eventually, to decomposers. Food webs represent many interconnected food chains and illustrate pathways in which energy and matter are exchanged in an ecosystem. Matter is recycled through the trophic levels. Energy flows through the trophic levels in a single direction. Energy transfer in an ecosystem is inefficient. A great deal of energy is transferred to the environment as heat while moving through the different trophic levels. Ecological pyramids allow quantitative data to be expressed in a visual manner. The three types of ecological pyramids are energy, numbers, and biomass.

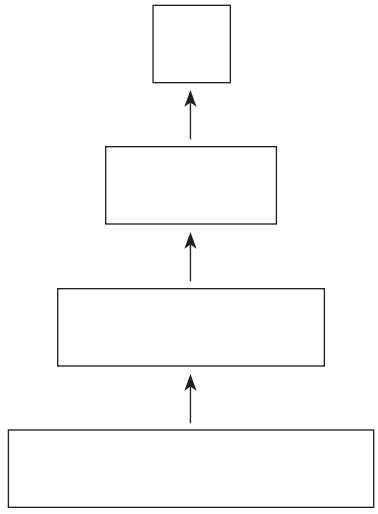
1.3 Questions

Knowledge

1. Define the following terms.
    - **a.** primary consumer
    - **b.** secondary consumer
    - **c.** tertiary consumer
    - **d.** decomposer
    - **e.** food chain
    - **f.** food web
    - **g.** trophic level
    - **h.** ecological pyramid
    - **i.** biomass
    - **j.** pyramid of numbers
    - **k.** pyramid of energy
    - **l.** pyramid of biomass
2. In general, what percentage of energy is passed on between one trophic level and the next trophic level in the energy pyramid?
3. Concisely explain the meaning of arrows in a food chain.
4. Distinguish between producers and consumers.

Applying Concepts

5. Which group of organisms is always found at the starting point of a food web?
6. Record the following diagram in your notes. Use it to summarize the various relationships in a food chain. Each box represents a trophic level. Write the name for each trophic level in the proper box. Use these choices: Producer, Primary Consumer, Secondary Consumer, and Tertiary Consumer. Additional names can be attached to the different trophic levels. Identify which boxes match the names herbivore and carnivore.



    - **a.** Explain what is represented by the arrows that connect the trophic levels.
    - **b.** Describe the significance of the decreasing width for each pyramid box in terms of available matter and energy at each level.
    - **c.** Predict where decomposers would be found in the diagram.